International Journal of Mechanical Engineering and Technology (IJMET)
Volume 10, Issue 01, January 2019, pp. 232–241, Article ID: IJMET_10_01_023
Available online at http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=10&IType=1
ISSN Print: 0976-6340 and ISSN Online: 0976-6359

EXPERIMENTAL ANALYSIS OF STRESS DISTRIBUTION OVER A HYBRID COMPOSITE WITH A CENTRAL HOLE

Gopalakrishnan S, Surya Prakash R, Rahul R, Ajith Kumar K
Department of Mechanical Engineering,
SRM Institute of Science and Technology, Chennai, India

ABSTRACT

In this paper we have analyzed the stress distribution over a rectangular specimen with hybrid composite material at its central hole. Using Vacuum bag technique the material has been fabricated and it consists of carbon and glass fiber with epoxy. The cross ply lamina arrangement with alternate carbon and glass has increased the strength of the structure. This is because carbon properties are high compared to glass. The cutouts made in typical aircraft and automobile components reduce the weight and bulking load carrying capacity of the aircraft according to the weight reduction law. Three specimens were used to carry out experimental investigations as per ASTM D5766 in the universal testing machine. We have analyzed and compared the results of the stress concentration in the rectangular specimen with a hole using FEA

Key words: Composite, finite element analysis, stress concentration, tensile strength.

Cite this Article: Gopalakrishnan S, Surya Prakash R, Rahul R, Ajith Kumar K, Experimental Analysis of Stress Distribution Over a Hybrid Composite with a Central Hole, *International Journal of Mechanical Engineering and Technology* 10(1), 2019, pp. 232–241.
http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=10&IType=1

1. INTRODUCTION

A material with a circular center hole under transverse loading condition are widely used in all application in different field of industries and engineering application as space vehicle, aircraft, automobile, marine etc. The circular cutout is introduced in a part to facilitate with a joints in such case stress concentration factor (SCF) is increases near the hole due to loading condition. SCF increase creates a change in the uniform stress pattern in the entire part and may lead to failure. Hybrid composite are composite with two different properties combining together to give more strength at low price, use of carbon fiber alone may be expensive to manufacture in case of using a hybrid composites of carbon and glass for the required part is needs to be studied. Many researchers have analyzed the case in different manner about stress concentration with circular holes.

2. LITERATURE SURVEY

Moon et al. [1] evaluated the stress field and relationship between isotropic and orthotropic composite plate subjected to transverse loading. It has been analyzed stress in xy direction is seen maximum on the whole boundary along the width direction of the plate. Yasar and arslan [2] has studied the coupling effect behavior is different in laminated composite plate behavior with hole for two cases in which one is single layer and other layer in composite plate both having same material properties and fiber orientation angle. Jain and sanyal [3] analyzed SCF for all stresses increased slightly with increasing of t/A at any D/A ratio for almost all cases of material. The t/A ratio plays a significant role in orthotropic plates and negligible role in isotropic plate and 3D analysis is most suitable for orthotropic material. Pan et al. [4] proposed a general solution for the composite laminates with a hole using BEM (boundary element method). It has been shown that even with a very coarse mesh the loop stresses along the hole predicated by the presence formulation are very close to the analytical solution. Neha and mohite [5] has studied the different structure element under transverse loading conditions and revealed that the FEA results for thin composite plate with SHELL 181 are in good agreement with analytical solution for the plate. Murat et al [6] have analyzed the failure loads obtained from Hoffman and Tsai-hill criteria are given for two composite materials with different fiber orientation angles. When the fiber orientation increases, the failure load decreases in tensile and compressive loading condition. Jain [7] analyzed the reduction of stress concentration by using coaxial auxiliary holes were introduced nearby the main hole. Arumugam et al. [8] proposed carbon / epoxy ultimate strength by tensile loading from acoustic emission technique . keshavamurthy [9] Investigated about the tensile properties fiber reinforced ply laminated composite.

3. DESCRIPTION OF PROBLEM

To study the stress concentration factor around the hole in orthotropic specimen model specimen with dimension of 36X250X2.8mm. This dimension is taken as per the ASTM standards D5766.

Table 1 The material properties of the orthotropic specimen

Material properties	**Carbon fiber**	**Glass fiber**
E_{11} (Gpa)	230	39
E_{22} (Gpa)	15	8.6
E_{33} (Gpa)	15	8.6
μ_{12}	0.25	0.28
μ_{13}	0.25	0.28
μ_{23}	0.25	0.28
G_{12} (Gpa)	13.7	3.8
G_{13} (Gpa)	13.7	3.8
G_{23} (Gpa)	6	3.8

The specimens are subjected to uniformly distributed load with P. The specimen is fabricated by arranging glass and carbon fiber alternatively keeping at the top and bottom

with glass fiber. Tensile testing and FEA software analysis to find out the stress concentration factor near the hole of the specimen.

4. EXPERIMENTAL TESTING

Hybrid composite laminate plate prepared using glass and carbon fiber with epoxy resin. Fabrication of the plate is a combination of glass and carbon. The glass lamina is placed on top and bottom of the plate and in-between alternative of carbon and glass lamina were placed one over another with application of epoxy. Totally 11 layers are used to fabricate a plate with the size of 300mmx300mm.

Fabrication done by using vacuum bag technique and this method gives a proper finishing to the surface. Specimens are dimensioned by water jet cutting machine as per ASTM standard. In aircraft there are various force acting on it and vertical and horizontal force with an opposite force that type of forces act on aircraft so to find these type of loading in aircraft using tensile testing. Tensile testing is a form of pulling a specimen on both the ends. Due to elongation it measures displacement with respect to force act on it.

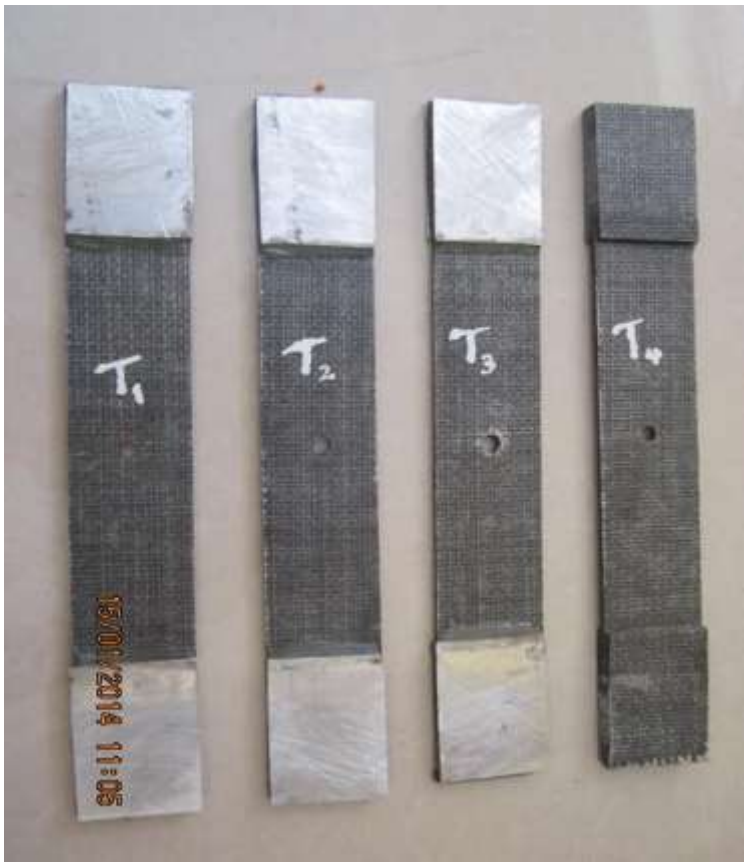

Figure 1 Tensile Test Specimen

Figure 2 Experimental Setup in UTM

After cutting a specimen the tabs are attached to it by epoxy resin with 50mm x 36mm and the gauge length of 150mm. tensile tests are carried out on the specimen in universal testing machine (figure 2).

5. FINITE ELEMENT ANALYSIS

Finite element method was chosen to analysis the orthotropic specimen. The structural element used 3D shell element, 4node 181 in ANSYS. Mapped meshing were gives more effective to find the stress concentration near the hole. The full specimen was analyzed with a specified dimension. Purpose of using FEM is to find the exact place of the maximum stress near the hole. The layup of the material are also mentioned as per the procedures with the same thickness (figure 3).

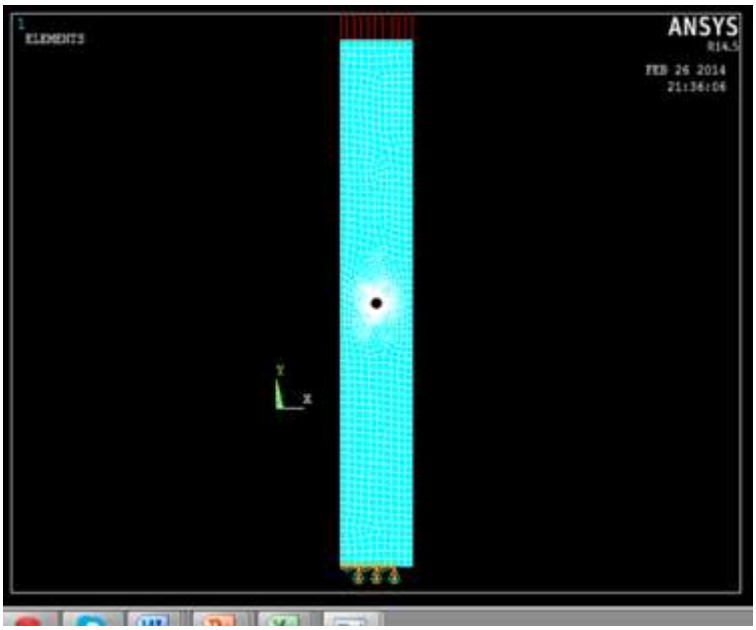

Figure 3 Composite Laminate With Central Hole Under Study With Boundary Conditions

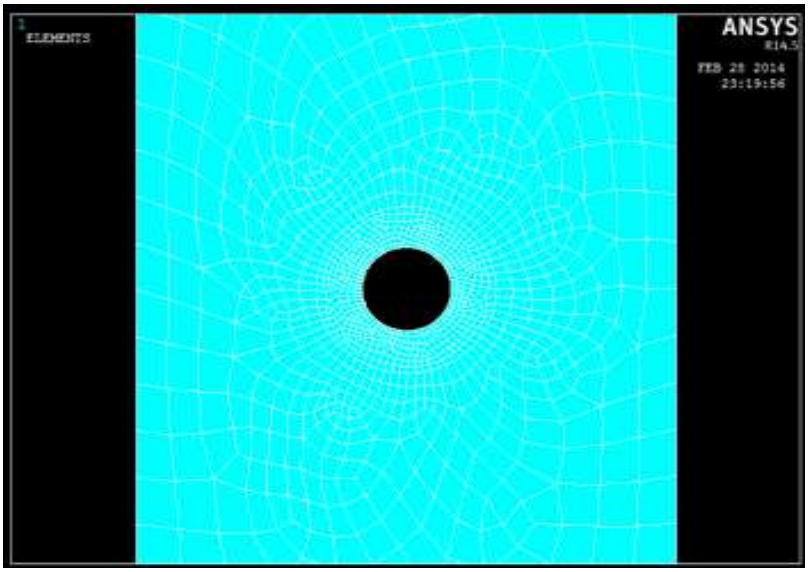

Figure 4 Mapped Meshing Around the Circular Hole

After created meshing on a specimen , near the hole need to create fine meshing to know the exact value of stress around the hole.

6. RESULT AND DISCUSSION

The result of tensile test by experimental testing is obtained for the material is presented in graphical explanation form (figure 5,6,7) and tested specimens(figure 4) and the specimen is clearly visible the stress concentration nears the hole due to tensile loading. When the load acting on the specimen it leads to failure along the fiber direction.

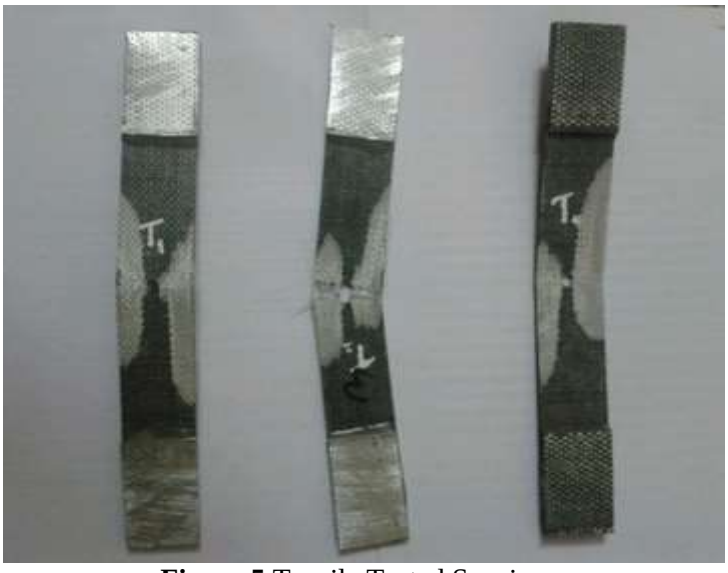

Figure 5 Tensile Tested Specimen

The stress-strain curve, time-displacement, strain-time curve are listed for 3 specimen per testing. The stress strain curve is linearly increasing as per the hook's law and the stress maximum at 286.83 MPa at the load of 23KN. Young's modulus where is more when compared to glass and it is less than carbon specimen. Its gives an intermediate value of young's modulus.

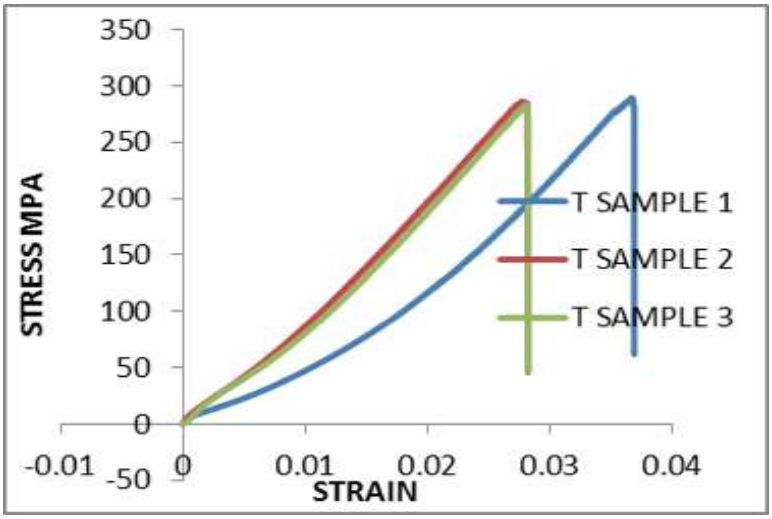

Figure 6 Stress vs. Strain Curve For Tensile Test

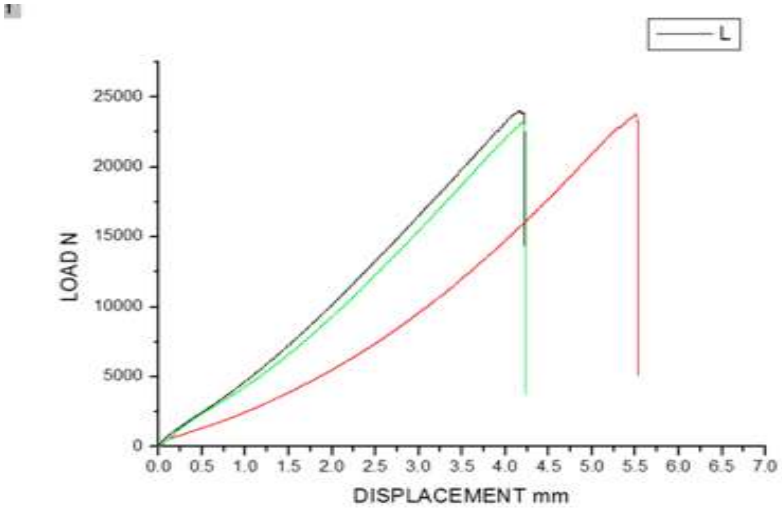

Figure 7 Load vs Displacement

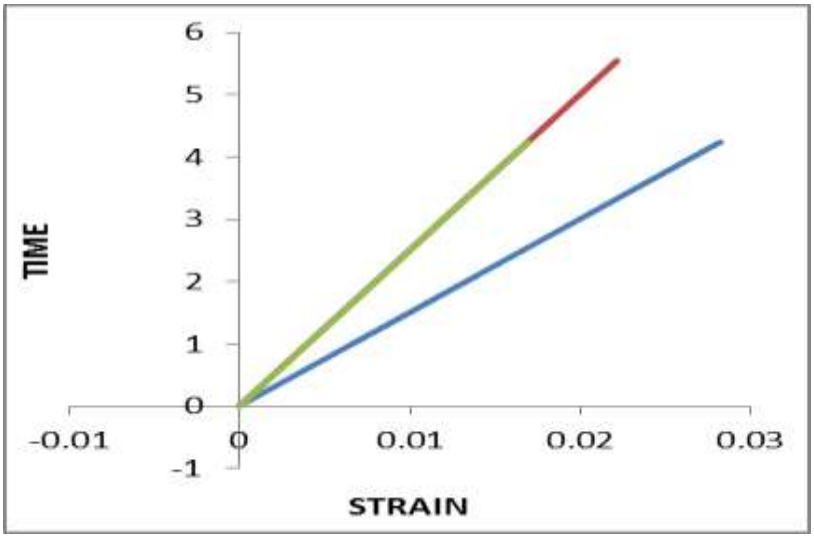

Figure 8 Time vs Strain

Table 2 Peak stress

s.no	Trail 1 (MPa)	Trail 2 (MPa)	Trail 3 (MPa)	Avg (MPa)
$0^0/90^0$	276.96	298.65	284.89	286.83

Table 3 Peak load

s.no	Trail 1 (KN)	Trail 2 (KN)	Trail 3 (KN)	Avg (KN)
$0^0/90^0$	22.8	23	23.4	23

Table 4 Young's modulus

s.no	Trail 1 (GPa)	Trail 2 (GPa)	Trail 3 (GPa)	Avg (GPa)
$0^0/90^0$	175	151.89	197.67	174.85

Analysis take place as per the experimental procedure and the results of the analysis is equal to the experimental value as the maximum stress and young's modulus value of it. When the area is more than to diameter describes the specimen maximum stress near to the circular center hole.

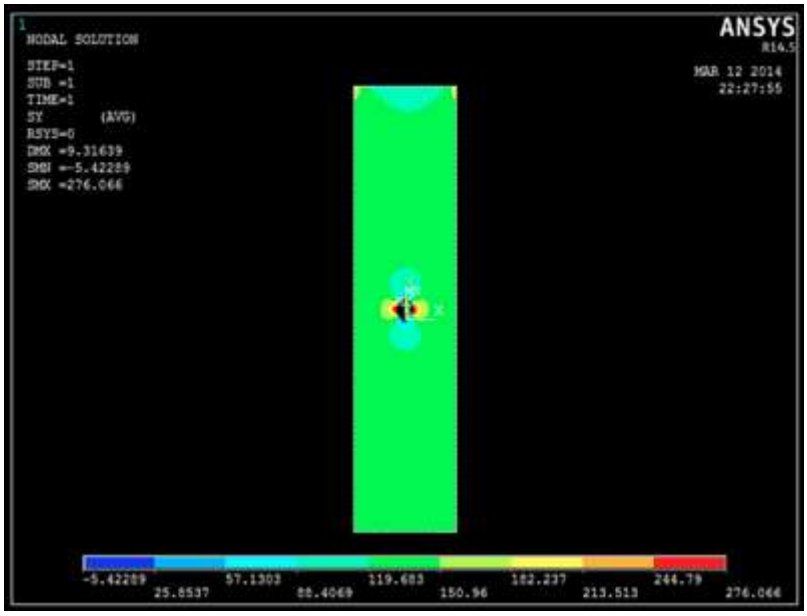

Figure 9 Nodal Maximum Stress around the Hole in Y axis

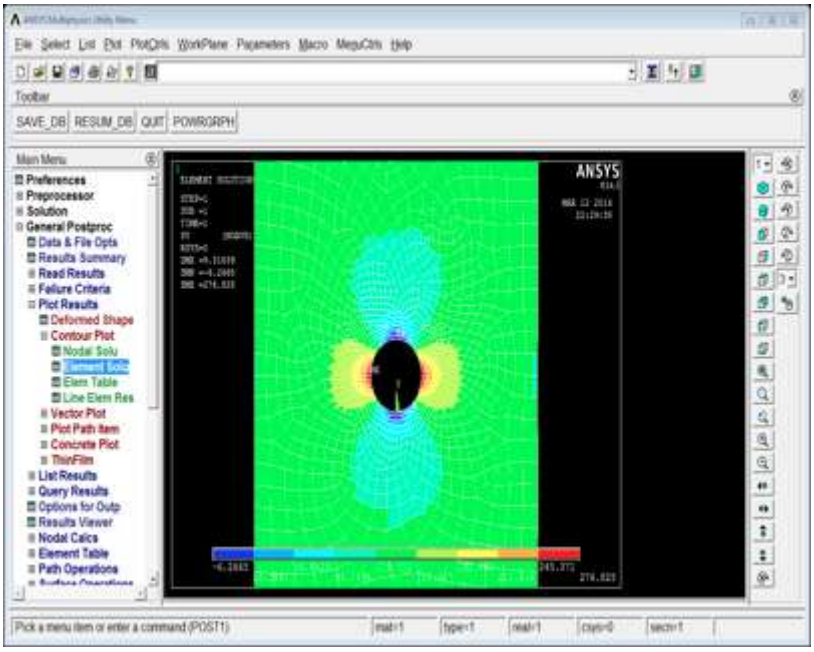

Figure 10 Element Maximum Stress in Y axis

The result of maximum stress along the fiber direction and near the circular cut out. It is clearly visible the stress concentration of the specimen.

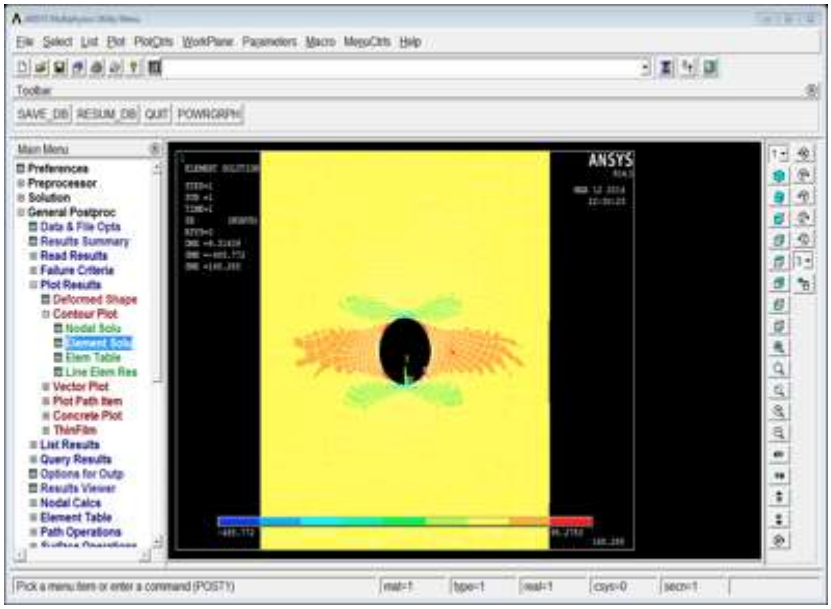

Figure 11 Element Stress Near Hole in X-axis

The tensile tested specimen and the FEA analyzed result are with the stress concentration throughout the specimen. when the loading is in y-direction and stress distribution along the x-axis. The maximum stress concentration near the circular cutout.

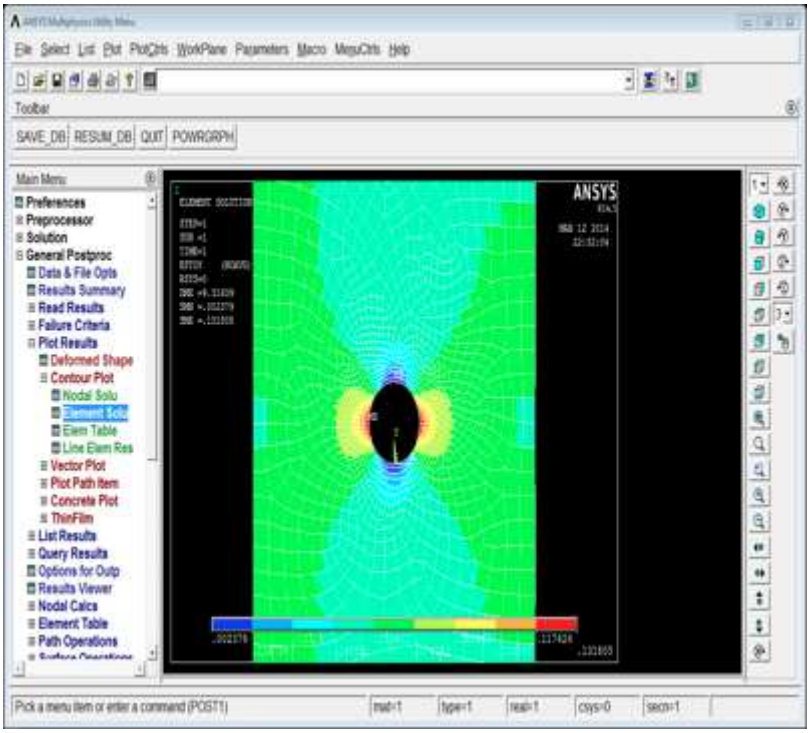

Figure 12 Maximum Stress Concentration Near the Hole

7. CONCLUSIONS

The values of the experimental and numerical values are almost same and the maximum stress are near the hole when subjected to uniform tensile loading condition. Using of carbon fiber in entire model will increase the cost but it has a solution to use hybrid material in specific part for moderate strength requirement. Hybrid material can be a good alternative material.

REFERENCES

[1] Moon Banerjee, N.K. Jain and S.Sanyal, "stress concentration in isotropic & orthotropic composite plates with center circular hole subjected to transverse loading, international journal of mechanical and industrial engineering (IJMIE) ISSN No .2231-6477,vol-3,iss-1,2013.

[2] M.Yasar kaltakci and H.M.Arslan "Stress concentration of symmetrically laminated composite plates containing circular hole,"IEEE Trans. Electron Devices, Iranian journal of science & technology, vol.30, no. B4, Oct 2009.

[3] N.K Jain, "3D of stress concentration factor and deflection," International Journal Of Mechanical Engineering Researches And Development (IJMERD), ISSN 2248-9347, Vol-1, pp.01-1 may 2011.

[4] E.Pan, B.Yang, G.Cai, F.G.Yuan, "stress analyses around holes in composite laminate using boundary element method,IEEE Trans, Electron Devices, vol 25, pp.31-40,aug 2001.

[5] Neha V. Potdar, Maruti A.Mohite, IOSR journal of mechanical and civil engineering, Vol 7, issue 6 pp.37-40, Jul -Aug 2012.

[6] Murat H, Huseyin R Yerli, "Effect Of Circular Holes On Cross-Ply Laminated Composite Plate", Vol 34,oct 2008.

[7] Jain N.K , " The reduction of stress concentration in a uni- axial loaded infinite width rectangular isotropic/ orthotropic plate with central circular hole by coaxial auxiliary holes" IIUM Engineering Journal, Vol. 12, No. 6, 2011

[8] *V. Arumugam, R. Naren Shankar, B.T.N. Sridhar and A. Joseph Stanley,*"Ultimate Strength Prediction of Carbon/Epoxy Tensile Specimens from Acoustic Emission Data", J. Mater. Sci. Technol, vol 26, march 5th, 2010

[9] Keshavamurthy Y C , Dr. Nanjundaradhya N V , Dr. Ramesh S Sharma, Dr. R S Kulkarni, "Investigation of tensile properties fiber reinforced ply laminated composite", International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 2, Issue 4, April 2012.